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Contribution of renewable energy sources to electricity production in the La Rioja Autonomous Community, Spain. A review

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Abstract

The implementation of the emissions market should imbue renewable energies with a greater degree of competitiveness regarding conventional generation. In order to comply with the Kyoto protocol, utilities are going to begin to factor in the cost of CO_2 (environmental costs) in their overall generating costs, whereby there will be an increase in the marginal prices of the electricity pool.

This article reviews the progress made in the La Rioja Autonomous Community (LRAC) in terms of the introduction of renewable energy technologies since 1996, where renewable energy represents approximately only 10% of the final energy consumption of the LRAC. Nonetheless, the expected exploitation of renewable energies and the recent implementation of a combined cycle facility mean that the electricity scenario in La Rioja will undergo spectacular change over the coming years: we examine the possibility of meeting a target of practical electrical self-sufficiency by 2010.

In 2004, power consumption amounted to 1494 GWh, with an installed power of 1029.0 MW of electricity. By 2010, the Arrúbal combined cycle facility will produce around 9600 GWh/year, thereby providing a power generation output in La Rioja of close to 2044.7 MW, which will involve almost doubling the present output, and multiplying by 8.9 that recorded in this Autonomous Community in 2001.

Keywords: Renewable energy; EU targets-2010; La Rioja

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1. Introduction

The problem of energy is one that has always been closely tied to the development of human civilisation. Most of the forecasts on trends in energy needs [1–3] indicate that a further challenge will be the likely increase in demand in certain heavily populated countries, such as China, which are advancing from underdeveloped economies to industrial-type ones, and the inevitable impact this will have on the current energy model. Against this backdrop of dependency, on the one hand, and criticism of the existing model on the other, the European Union (EU) is playing an active role in the field.

The development of renewable energy has long been one of the central objectives of community energy policy: in 1986 the Council of Europe mentioned initiatives to promote renewable energy sources as being one of its energy targets [4]. In 1995, EU member states consumed 1367 million tonnes of oil equivalent (Mtoe) ($1\,\mathrm{Mtoe} = 41.868 \times 10^{15}\,\mathrm{J}$) of energy. Renewable energy sources contributed just 5.44% of this figure and were clearly being underused. With the ALTENER programme, the European Commission, in its White Paper "An Energy Policy for the European Union" [5], set out its ideas on community targets, and the instruments of energy policy needed to achieve them. At the same time, economic growth and rising energy needs increase the risk of harm to the environment, with renewables energy sources emerging as one of the most effective solutions [6]. In order to promote the use of renewable energy, the Commission adopted the "Green Paper" [7]. Table 1 [8] shows the targets for production from renewable energy for 2010 by country.

In Spain, RES have been successively promoted by the 1986 Renewable Energy Plan (REP) [9] and the National Energy Plan for 1991–2000 and 2000–2003. The 1997 Electricity Industry Act 54/1997 [10] prioritised deregulation of electricity market, establishing a special framework or *regime* for renewable energy which would allow guaranteed access to the grid, while at the same. Royal Decree 436/2004 [11], enacted on 12 March 2004, establishes the new methodology for payment under the special system.

An analysis of trends in terms of the objectives set forth for 2011 (Fig. 1) [12] reveals that the target of 12% for renewable energies is still far from being attained, as it has barely increased since the approval of the Plan for the Development of Renewable Energies.

Table 1
Targets by country for 2010

	Percentage	TWh	Percentage without large hydro
Germany	12.5	76.4	10.3
Austria	78.1	55.3	21.1
Belgium	6.0	6.3	5.8
Denmark	29.0	12.9	29.0
Spain	29.4	76.6	17.5
Finland	35.0	33.7	21.7
France	21.0	112.9	8.9
Greece	20.1	14.5	14.5
Ireland	13.2	4.5	11.7
Italy	25.0	89.6	14.9
Luxembourg	5.7	0.5	5.7
The Netherlands	12.0	159	12.0
Portugal	45.6	28.3	21.5
United Kingdom	10.0	50.0	9.3
Sweden	60.0	97.5	15.7
EU	22.1	674.9	12.5

EU directive on promotion of electricity from renewable energy sources.

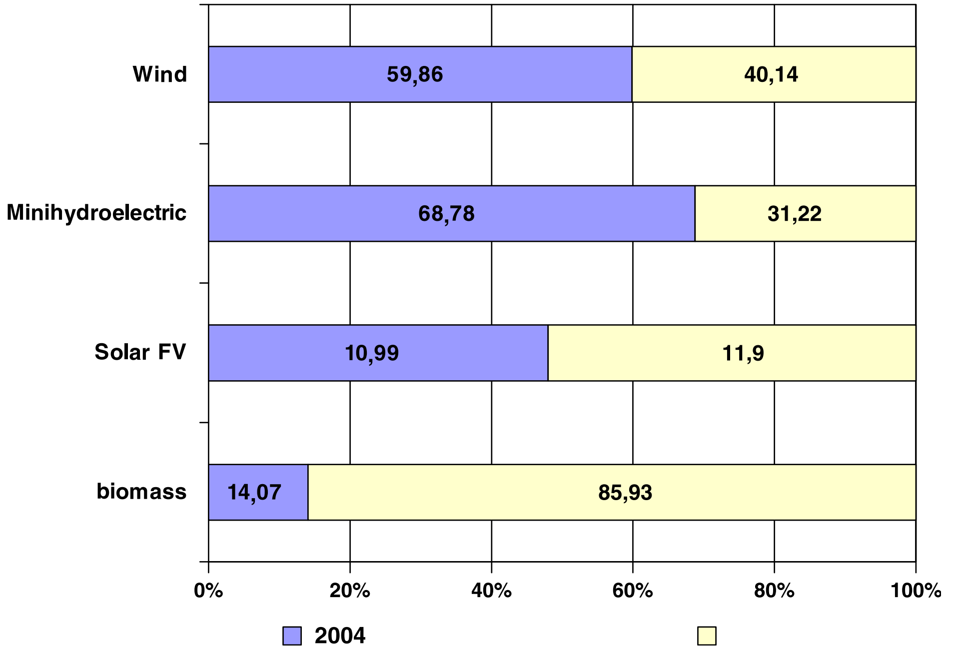

Fig. 1. Execution in 2004 of targets for 2011 in Spain. *Source*: CNE.

Furthermore, the degree of outside dependence persists due to the increase in the consumption of natural gas within the structure of domestic consumption itself.

The La Rioja Autonomous Community (LRAC) consumed 48,394 toe of renewable energy in 1996. Biomass registers the highest percentage (69.9%), followed by hydroelectric (30.0%), with solar and wind energy recording a lower and practically insignificant percentage.

Current consumption of renewable energy represents 10% of final energy consumption with, moreover, a slight downward trend over the past few years. Nevertheless, the potential for use of renewable energy is very high, as can be seen in the data for annual radiation given in the Solar Atlas, and in the data for wind, biomass and MSW energy that have so far gone almost unused.

2. Renewable energy technologies

2.1. Photovoltaic solar energy

2.1.1. Solar radiation

La Rioja, like most of the rest of Spain, presents very favourable climate characteristics for solar energy use. There are annual averages for sunshine of 2000–2400 h. The average for daily solar radiation is 1.6–1.8 kWh/m^2 in winter, rising to 4.8 kWh/m^2 in summer, compared to averages of over 5 and 7 kWh/m^2 in the south of Spain. Albeit not the highest, it is certainly greater than the solar potential of Germany, Sweden, etc. [13].

We have, therefore, provided the highly informative map below, featuring the isolines for annual average sunshine in La Rioja, by area (Fig. 2a) and for each month of the year in kWh/m^2 day (Fig. 2b).

The average values for annual hours of sunshine for these areas are:

Zone: Centre and Lower Rioja: 2200–2300.
Zone: Lower Rioja: 2000–2200.
Zone: Mountain and North: 1900–2000.

2.1.2. Current situation

The present use of solar energy is way below its potential. In particular, the thermal solar sector is very small, with a total of 247 solar collectors in 23 facilities intended for heating and hot water production, which represent an annual saving of primary energy of 53.1 toe. Insofar as photovoltaic solar energy is concerned, and according to information gathered and to data included in the publications of the Institute for Energy Saving and Diversification, *Instituto de Diversificación y Ahorro Energético* [14], by the end of 1995 La Rioja had 48 photovoltaic solar energy installations, with an overall peak power output of 5.42 kWp. Twenty-seven new installations were introduced in 1999 with an output of 31 kWp, compared to 3953 kWp for Spain as a whole, and 14 installations in 2000, with an installed power of 52 kWp [14].

Today, there are numerous photovoltaic solar panel installations, located in rural areas without conventional electrification, with an installed total power of 86.3 kWp, representing a saving of primary energy of 6.8 toe. The majority of these installations correspond to holiday homes and picnic areas, which generally have one or two solar panels and an installed power of 50–100 Wp. They are all small installations, and include

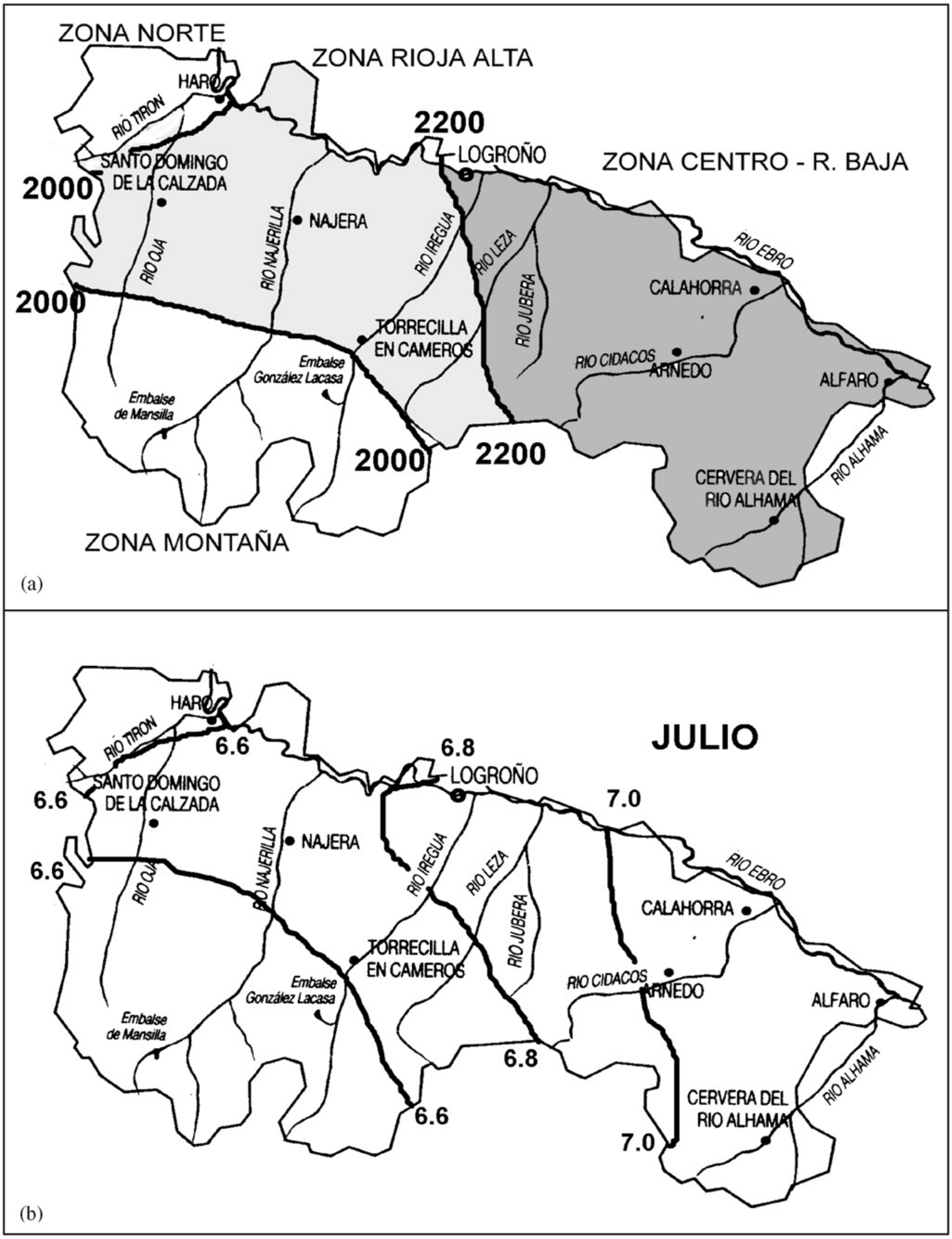

Fig. 2. Isolines for (a) annual average sunshine and (b) average daily radiation figures for July.

applications, such as repeaters, road signalling systems, agricultural and cattle sheds, pumps, signal repeaters, lighting in remote areas, etc. For example, as part of the SAIH-EBRO project, the firm Sintel has carried out 150 installations of photovoltaic systems for the supply of control points and radio repeaters, with a total of 2400 modules of 55 Wp.

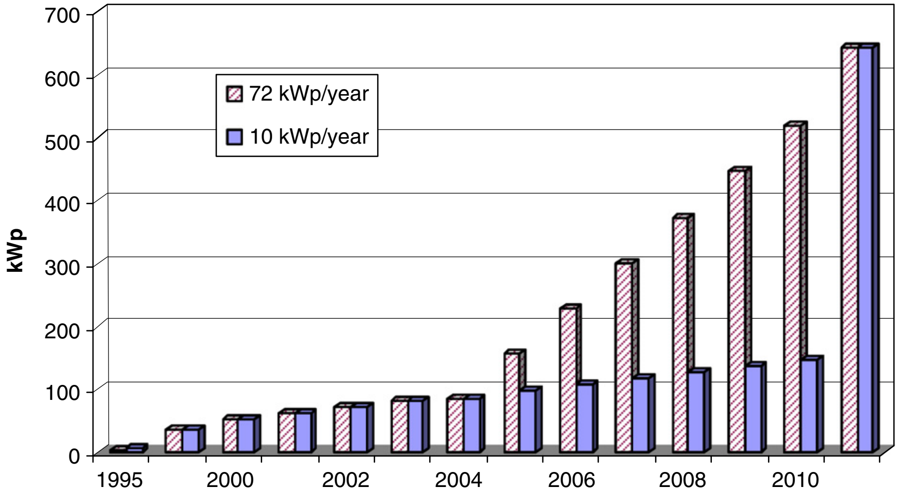

Fig. 3. Estimations for meeting the targets of the La Rioja plan solar photovoltaic plan.

It involves an automatic system for hydrological control and voice communications that takes in the entire basin of the River Ebro. Eighteen installations of this kind have been performed in the LRAC (e.g., the irrigated lands of Najerilla).

The projects have largely been promoted by the Administration, with a view to providing a degree of electrification for remote establishments of this kind. As for the passive use of solar energy, i.e., so-called bio-climatic architecture, almost nothing has been done.

As may be seen in Fig. 3, according to Forecast (a), with linear growth at a rate of 10 kW/year, only 28% of the final target will be achieved, whereas at a rate of 72 kWp/year (Forecast (b)), the figure would be 80%. The target is therefore overly ambitious, although a very significant increase is expected between 2005 and 2008 due to the approval of the new payment for renewable energies under Royal Decree 436/04 [11] and an increase in the capacity power of installations eligible for grants from 5 to 100 kWp. Nonetheless, solar energy's contribution to the energy balance would still only be about 2 ktoe, a relatively insignificant figure in terms of energy planning.

It is estimated that the number of potential users over the coming 8 years may reach a figure of 300 dwellings and 50 industrial, agricultural and livestock facilities. The sum of all these installations would account for an installed power of 576 kWp, at a rate of 72 kWp/year. This would represent an annual investment approaching 1.08 M€ and an annual saving in primary energy of 7.4 toe.

By way of a final overview, the plan foreseen for 2010 with regard to solar energy is presented (4664 m^2 of thermal and 624 kWp of photovoltaic). As may be observed, it is a proposal that aims to be realistic, given the difficulties that have so far been forthcoming in the development of this renewable energy.

2.2. Biomass energy

Biomass is versatile since it can be used to produce electricity and heat or as transport fuel as required and, unlike electricity, it can be stored simply and normally economically

[15]. Production units can vary in size from very small ones to ones of thousands of megawatts.

For the EU as a whole a realistic target is considered to be the tripling of the present figure of 44.8 Mtoe by 2010, provided effective measures are taken. This would mean an additional biomass consumption of 90 Mtoe, equivalent to 8.5% of the total energy consumption forecast for that year. In some EU member states—Austria, Finland and Sweden—this renewable source of energy already represents 12%, 23% and 18%, respectively, of principal energy supply.

2.2.1. Forest waste

These projects for harnessing forestry biomass for energy purposes must be framed within integrated management of mountain areas. There are certain benefits, such as the contribution to improving management of mountain areas (hill clearing, fire prevention), harnessing of natural waste for energy production and job creation. But there are also barriers, including the alternative uses of the by-product of the wood industry, the fact that the availability of the resource is limited depending on the site and the need to improve transport logistics.

In order to assess the energy potential of forest waste, two groups were defined: waste from timber treatments (first transformation) and those resulting from the wood transformation industry (furniture and carpentry). The potential energy total of this waste is 34,500 toe. These products can be used for energy, by means of their combustion in boilers and homes. Considering an installation potential of 50% with respect to the available energy in this type of waste, this would mean an energy saving in primary energy of approximately 17 ktoe.

2.2.2. Agricultural waste: cereal straw

Both cereal straw and vineyard prunings are interesting in terms of energy saving. Considering that 61% of cereal straw has a direct use as fertiliser or animal feed or bedding, only the remaining 39% has energy potential. This totals 34,905 toe. With this value, and taking the characteristic calorific energy of this waste as a starting point, a viability study has been carried out with the aim of evaluating the possibilities of taking advantage of the energy to produce electricity.

In Table 2, the main data corresponding to the most interesting alternative are presented (cycle plant combined with gas turbine).

2.2.3. Agricultural waste: vineyard prunings

From an energy point of view, vineshoots can be of great interest. Indeed, it is a product that, to a greater of lesser extent, has to be pruned every year and removed from the vineyards. This vineshoot energy could be used jointly with cereal straw in an electricity generation plant. Use of 50% of the vineshoot energy would mean a saving in primary energy of 27,360 toe/year.

2.2.4. Municipal solid waste

From the typical composition of the MSW from each of the three areas that have been considered in the LRAC, the potential energy total for MSW has been evaluated at 22,850 toe/year. In the immediate future, an MSW plant is to be built for Logroño. This will deal with more than 70% of the total waste generated in La Rioja. By means of

Table 2
Summary of the most favourable proposal

Analysed alternative of greatest interest (combined cycle with gas turbine)	
Yearly consumption of biomass	139,654.4 t
Yearly consumption of natural gas	9,990,000 Nm^3
Condensation turbine	20.9 MW
Gas turbine	4.1 MW
Electric power generated the first year	183 GWh
Electric billing the first year old	11.50 M€
Investment	25.44 M€
Annual costs of exploitation	5.34 M€/year
Time of simple return	4.15 years
Internal rate of return	12.66%
Time of updated return	5.6 years

Table 3
Overall energy potential of the biomass and current level of exploitation

Type of biomass	Energy potential (toe)	Potential exploited (toe)	% Exploitation
Agricultural waste	203,930	—	—
Forestry waste	48,920 + (45,770)	26,900	55
Livestock waste	(185,600)	—	—
MSW	18,240	—	0
Industrial waste	36,067	7900	22
Total	30,7157	34,800	11

anaerobic decomposition of the organic matter in the MSW, biogas is generated. The generated biogas can be used as fuel for electricity generation by means of internal combustion engines, with the possibility of taking advantage of the heat energy from the combustion gases and the motors cooling, to satisfy the heat demands of the plant itself (co-generation).

Supposing that 60% of the energy potential of MSW is transformed to biogas, it is an equivalent production of 33.2 million cubic metres of methane under standard conditions. It represents an electric power installed in motors of 400 kW and an annual electricity production of 3190 MWh, which means a saving in primary energy of 13,700 toe.

Table 3 presents the overall energy potential of biomass, as well as its current level of exploitation. This percentage has been estimated without taking into account the energy potential of either livestock waste or forestry waste from primary processing.

2.3. Wind energy

The great technological development experienced in the wind industry and the existence in the Autonomous Community of La Rioja of large areas with important resources has led to the introduction of numerous wind farms, requiring the local government to intervene to organise these resources.

The development of wind technology in recent years has been spectacular, both in terms of the cost of the installed kilowatt and the availability of operation. At the beginning of

the 1990s, the average power of commercially installed wind turbines came to 200 kW, are now commercially available with a capacity of 1500 kW, and the first prototypes have been built of 3.5 MW and over. Annual operation time at full load for a turbine needs to be between 2000 and 2500 h for an installation to be profitable.

Spain currently registers an excess of requests for point connection, with their resolution being different depending on each Autonomous Community. By January 2005, requests had already been filed for grid access for 45,597 MW of wind energy, a figure that easily exceeds the 13,000 MW targeted for 2011, the capacity of the transport or distribution network for dealing with it, and even the territorial capacity for its development [16].

Initial observations suggest that the wind power potential in La Rioja is clearly located in the lower area of the Ebro valley, the Yerga Mountains being the place where wind speeds have been measured that would make the installation of a wind farm economically viable.

2.3.1. Installation potential

Wind energy was not exploited in La Rioja until 1998. The Yerga wind farm, with thirty-seven 660 kW wind turbines, was the first in this Autonomous Community and produces 6% of the energy consumed in La Rioja. Commissioning: 2000 with an investment of 21.5 M€ and an output of 24.42 MW, with an estimated production of 60 GWh/year. The Cabimonteros wind farm, the second to be installed in La Rioja, consists of seventy-five 660 kW output wind turbines. The wind farm has an estimated gross production of 134 GWh/year and net of 121,275 MWh/year. These two wind farms account for an approximate production of 180 GWh/year and the forecasts are for the generation of around 14% of the Autonomous Community's total electricity consumption. The third wind farm is that of Escurrillo, within the municipal boundaries of Arnedillo, Bergasa and Herce (Sierra La Hez) with thirty-three 1500 kW wind turbines and an output of 49.5 MW.

Wind power in 2001 amounted to 142.1 MW, following an investment of slightly more than 456.8 M€, producing around 125.6 ktoe [17]. With Yerga and Cabimonteros in operation, the region provides for 30.62% of its needs in electricity and 5.51% of its total energy.

At the beginning of 2004, there were five wind farms in operation, with a power output of 204 MW. Requests have been filed for the development of 37 wind farms with a power output of 675 MW and an estimated production of 1400 GWh/year. Furthermore, there is a series of wind farms that have already been given the go-ahead with a total power of 394.5 MW, as shown in Table 4 (Fig. 4).

In terms of financing, the wind farms have accounted for total accumulated investments of 123.5 M€ in 1998, 456.8 M€ in 2001 (including licences granted and installations under development that will come online in 2004) and with forecasts for an accumulated sum of 750.0 M€ by 2010. An aspect to be stressed is the employment figure involved in the construction of the wind farms, not only regarding direct employment, but also the repercussion on the business of other companies through the sub-contracting of work or the purchase of components.

When all these wind farms are in operation, they will account for an overall installed power of 536.6 MW, which together with the 128.4 MW liable for development up to 2010, constitute a total scheduled power, by that year, of 665.0 MW.

Regarding the electricity generated by the wind farms, in 1998 this amounted to only 3.0 ktoe, increasing to 26.8 ktoe in 2001, with estimates of 125.6 ktoe foreseen for 2010.

Table 4
Authorised projects for wind farms in La Rioja

Name	Output (MW)	Name	Output (MW)
Grávalos	30.0	Munilla-Lasanta	50.0
Préjano-Enciso	50.0	Larriba-Hornillos	50.0
Igea-Cornago	50.0	Raposeras	40.5
Las Planas	50.0	Gatún II	24.0
La Senda	50.0		
		Total	394.5

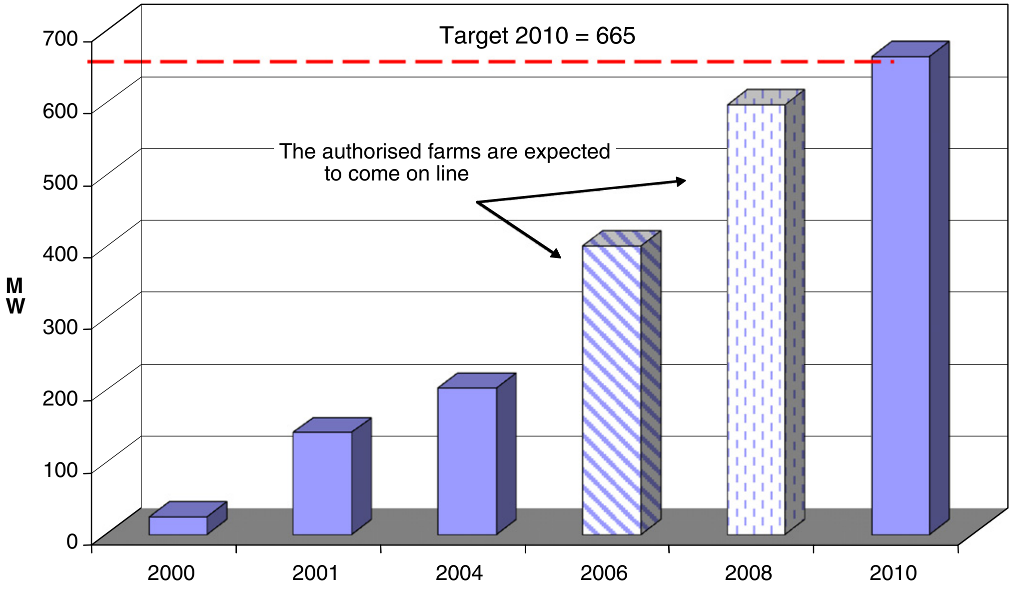

Fig. 4. Installed power in wind turbines in the La Rioja Autonomous Community.

As for the power of electricity generation, in 2010 wind energy will account for 40.4% of the total, with an electricity output that will represent 16.7% of the total produced (8754 GWh = 752.8 ktoe).

2.4. *Mini-hydropower*

Hydroelectric energy constituted, until the arrival of co-generation, the only electric power source in the Community of La Rioja, and the only local resource of any scale that contributes to meeting the energy needs in the region.

2.4.1. *Current situation*

The maximum theoretical limit on the hydroelectric energy of a river course over 1 year is usually referred to as the Gross Hydroelectric Potential. It constitutes an unattainable

value that represents the total energy provided by the flow over said period. It may readily be understood that, given that the flow is a seasonal and random parameter, varying along the length of the course, as is also the slope or height gradient, its exact calculation is highly complex.

A comparison between gross potentials appraised 20 years ago and present-day ones shows a significant drop in contributions. This may be due to several reasons, amongst which mention should be made of the possible seasonality of the last 30-year period, in which the effects of climate change have become apparent, and also the greater detail applied to data processing, in the case of the more eastern rivers of a markedly Mediterranean system.

Whereas the Gross Potential represents the upper limit of the hydroelectric energy, and depends on hydrologic characteristics: average annual flow and gross head, the Potential Power Available is that forthcoming after applying all the limitations imposed by the various factors: environmental, social and economic, which ultimately determine the feasibility of a hydroelectric installation. Accordingly, it may be concluded that the Gross Hydroelectric Potential in the LRAC, updated to 2001, records a significant drop, falling from 2424 to 1937 GWh/year [18] (Table 5).

2.4.2. Evolution of installed power

The entry into force of the REP (*Plan de Energías Renovables*), as well as supplementary schemes introduced by the Regional Government in support of renewable energies, has led to the commissioning in the LRAC of 15 hydroelectric installations, located on the basins of rivers Ebro, Oja, Najerilla and Iregua. Fig. 5 shows the distribution of the mini-power stations according to each watercourse.

Only one installation has been built on the River Oja. The new installed power accounts for 1.65% of the total power installed in the Autonomous Community over the period in question. Five new installations have been built on the River Najerilla and its network of tributaries. The power installed over the period in question has amounted to 2757 kW, accounting for 14.45% of the total. The River Iregua has been the site of four new installations. In total, these installations record a total power of 1582 kW, accounting for

Table 5
Hydroelectric potential of La Rioja (administrative community) in 2001

Basin	Surface stretch (km^2)	Minimum height (ASL)	Contribution of stretch (Hm^3)	Gross Lin. potential (GWh)	Technical potential (GWh)	Installable potential (kW)
Ebro	2209.6	260	395.1	581.25	149.41	64,765
Tiron-oja	705.8	435	276.1	140.01	4.03	18,716
Najerilla	1099.4	405	341.1	288.11	59.03	23,647
Iregua	691.8	360	202.0	285.91	53.06	26,274
Leza	533.9	345	174.7	56.49	10.17	8299
Cidacos	391.2	290	48.2	39.32	16.26	5886
Alhama		265		40.62	6.64	7592
Total	5631.7		1473.2	1431.71	337.97	155,179

Source: Inchausti. Logroño, 2001.

8.29% of the power installed in La Rioja over the past 16 years. Fig. 6 shows the evolution in the number of mini-power station projects in La Rioja between 1986 and 2001 [18].

The data forthcoming from the aforementioned sources, within the territory administered by the LRAC, indicate that 27 hydroelectric or mini-power stations were in operation, of which 23 were connected to the high or low voltage electricity grid, and the remaining four generated electricity for self-consumption, without the possibility, therefore, of selling any surplus. In total, the installed hydroelectric power in 1996 recorded a figure of 42.22 MW, and the annual energy obtained is estimated at 168.47 MWh.

The distribution of these installations by type of project is as follows: new power plants account for just over half (52%), followed by refurbishment-modernisation (25%) and enlargement projects (22%). The increase in installed power and production in the hydroelectric sector has gone from 22,921 kW and 104,803 MWh in 1980, to 42,221 kW and 168,471 MWh in 1996 and finally to 42,220 kW and 168,467 MWh in 2001.

As targets of the La Rioja Energy Plan, the aim is for the hydroelectric sector to contribute quantitatively with the following goals: Increase electricity production by means of its own resources by 52.4 GWh/year so that its own hydroelectric production reaches

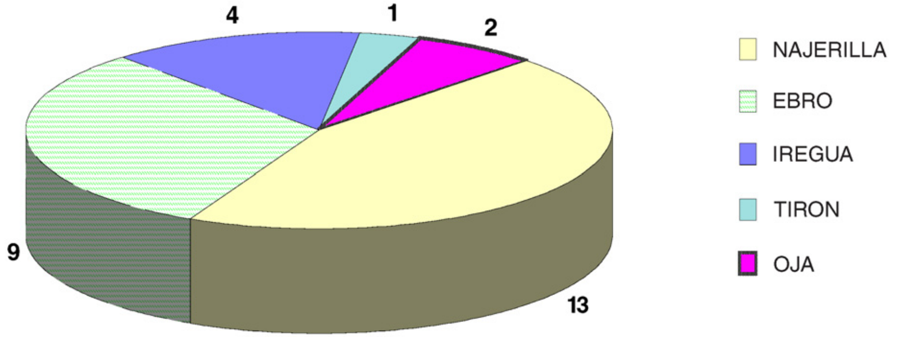

Fig. 5. Distribution, by basin, of the number of mini-power plants in the Community of La Rioja in 2001.

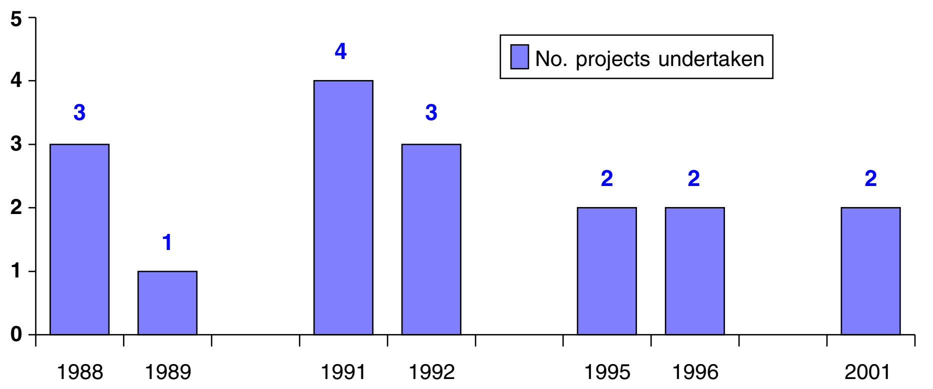

Fig. 6. Evolution in the number of mini-hydroelectric projects in La Rioja between 1986 and 2001.

222.8 GWh/year by 2010. The increase in hydroelectric power stands at 13.1 MW, with an estimated investment of 20 M€. This involves avoiding the emission of 49,700 t/year of CO_2 and 260 t/year of SO_2, by replacing conventional production with this renewable energy.

3. Forecasts for 2010

Figs. 7 and 8 reveal the trend in the consumption of electricity between 2003 and 2010, and its breakdown according to economic sectors. The forecasts for 2010 indicate the potential availability of 1644.7 MW and an electricity output of 8754 GWh, with consumption in La Rioja of only 1960 GWh, thereby allowing for the export of 6794 GWh, which represents 77.6% of the electricity generated, and 3.5 times the electricity consumed in La Rioja.

Electricity production in La Rioja has undergone major growth over the last decade, at the same time as the sources providing it have been diversified. In 1996, the source of electricity was largely hydroelectric (73%), with the remaining electricity produced in co-generation facilities, with natural gas power plants accounting for 18% and gas oil–fuel oil for 9%. The use of renewable resources in 1996 represented a total of 48.3 ktoe. Since 2001 the situation has changed radically, with electricity produced by wind energy being the most important (57%), followed by hydroelectric (31%) and with co-generation facilities accounting for 12%. In 2001, the total for renewable energies used amounted to 76.1 ktoe.

The wind power installed in 2004 was 204.1 MW. The estimated production in an average year is 312 GWh/year. On the other hand, hydroelectric plants, numbering 29, provide the distribution grid with around 168 GWh in an average hydrological year. Self-consumption in industries that have mini-hydroelectric power plants may be estimated at 2 GWh, on average. The fuel used by co-generation installations is natural gas or fuel oil (diesel). They began to be installed in La Rioja several years ago. The installed power at

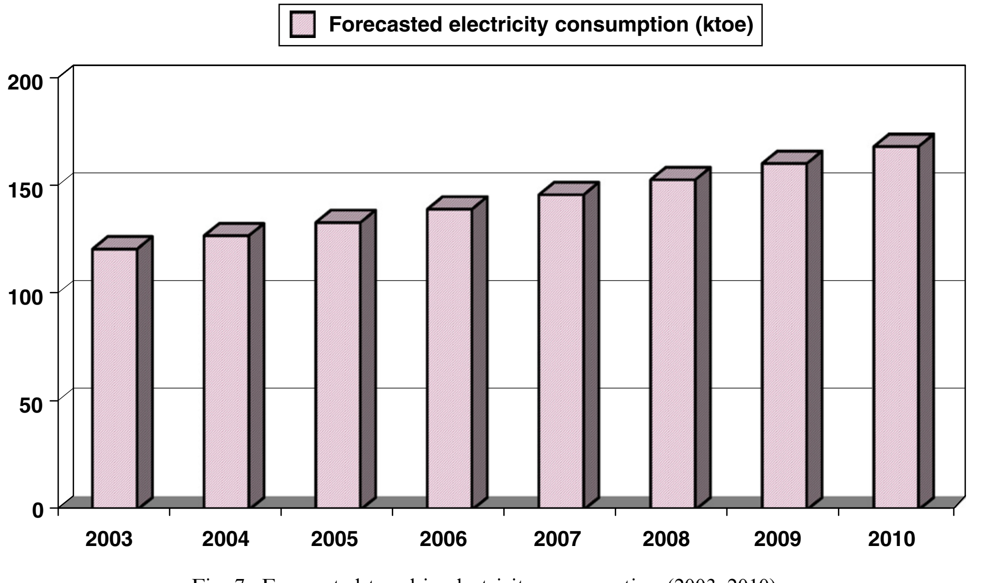

Fig. 7. Forecasted trend in electricity consumption (2003–2010).

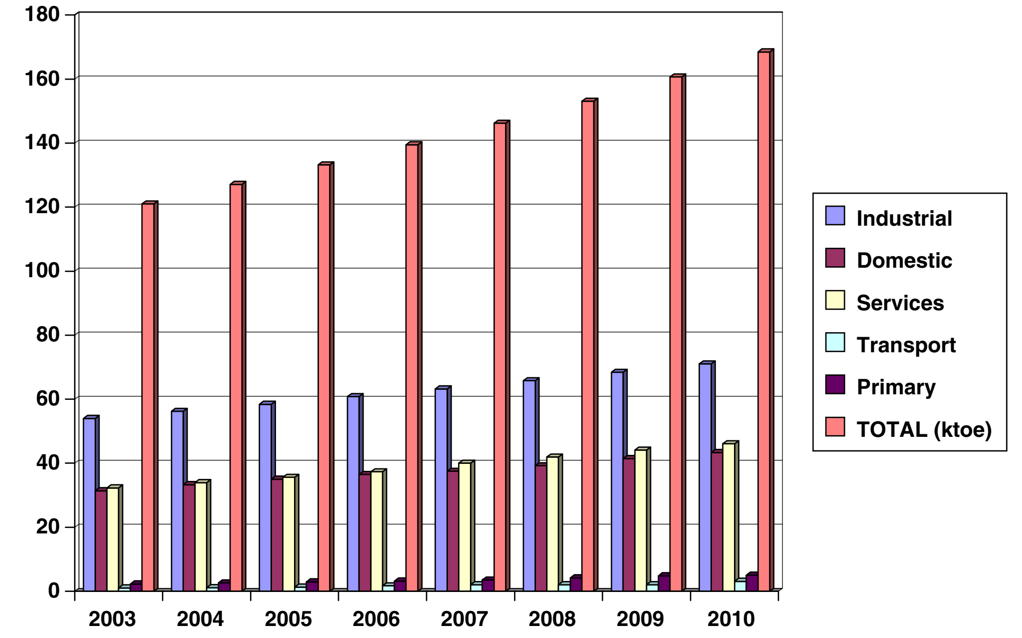

Fig. 8. Forecasted evolution in electricity consumption, itemised by sectors (2003–2010).

this moment is 43.6 MW. The output of co-generation plants in 2004 has been around 63,100 MWh, of which approximately 25,000 MWh are self-consumed and the remainder, i.e., 38,100 MWh, is supplied to the distribution grid. In accordance with this, the target set for 2010 is to attain a total level of use of 95.4 ktoe (Table 6).

4. Conclusions

Given the great potential of available energy resources, their future in La Rioja looks promising, since they can contribute significantly to regional development. In 2001, electricity consumption in La Rioja amounted to 1299 GWh, with 58.2% supplied from outside the Autonomous Community. Forecasts made in 2003 and prior ones for 2010 estimated the availability of a total power regarding electricity generation of around 1644.7 MW and an annual electricity output of 8754 GWh, with an estimated consumption in La Rioja of 1960 GWh, which would therefore mean the export of 77.6% of the electricity generated, and 3.5 times the energy consumed in La Rioja.

In 2004, the consumption of electricity amounted to 1494 GWh, with an installed power of 1029.0 MW of electricity, with the total electricity generated by renewable sources being 625 GWh, which represents 41.8 of consumption. By adding the output from the recently commissioned Arrúbal combined cycle power plant, around 450 GWh in 2004, it may be noted that they generated 72.0% of the electricity consumed.

By 2010, the Arrúbal combined cycle power plant will produce around 9600 GWh/year, which will represent a total power in combined cycle of 1200 MW, thereby providing an electricity generating power of around 2044.7 MW, which will mean almost doubling

Table 6
Renewable energies in the La Rioja autonomous community, comparative

Item	Current situation	Target 2010	Investments (M€)	Saving in primary energy (toe)
Solar energy				
Thermal collectors (m^2)	300	4664	2.7	267.2
Photovoltaic panels (kWp)	53.3	570	8.6	59.2
Biomass				
Forestry waste (toe)	26,900	37,900	12.0	11,000
Agricultural waste				
Cereal straw (toe)	—	34,905	25.5	34,905
Vine cuttings (toe)	—	27,360	5.0	27,360
MSW (toe)	1765	2765	1.0	1000
Mushroom waste (toe)		56,000	16.0	56,000
Industrial waste				
Oils (toe)	—	2200	4.0	2200
Tyres (toe)	—	1300	15.0	1300
Energy crops (toe)	—	3445	9.0	3445
Wind energy				
Power (MW)	204.1	665		
Production (GWh)	449.7	1596.4	456.0	87,100
Mini-hydro plants				
Power (MW)	42.6	55.7		
Production (GWh)	170.4	222.8	20.0	12,857

current electricity generating power, and multiplying by 8.9 the figure for the Autonomous Community in 2001.

In 2010, La Rioja's electricity generating capacity will consist of combined cycle (60.2%), wind farms (34.0%), co-generation (3.0%), mini-hydroelectric plants (1.8%) and biomass plants (1.0%). Insofar as the electricity generated is concerned, the combined cycle will account for 73.1%, wind farms for 16.7%, co-generation for 5.3%, mini-hydroelectric plants for 2.5% and biomass plants for 2.4%. The exploitation of solar energy is almost non-existent at the present time, but is expected to account for 0.24% by 2004.

References

[1] IEA. World Energy Outlook 2002. International Energy Agency, 2002.
[2] Hunt LC, Judge G, Ninomiya Y. Underlying trends and seasonability in UK energy demand: a sectoral analysis. Energy Econ 2003;25:93–118.
[3] Mitchell C. Energy policy for a sustainable future. Energy Policy (Special Edition) 2004;32:1887–9 [Foreword].
[4] European Commission. Directive 96/92/EC. The European Parliament and the Council, 1996.
[5] European Commission. An energy policy for the European Union. White Paper COM(95) 682 Final, Supplement on Energy in Europe, 1996.

[6] Dinçer I. Renewable energy and sustainable development: a crucial review. Renew Sust Energy Rev 2000;4:157–75.
[7] European Commission. Towards a European strategy for the security of energy supply. COM (2000)769 Green Paper, 2000.
[8] European Commission. General Directorate for energy and transport, B-1049 Bruxelles. European Communities, 2003.
[9] Act 82/80. Energy conservation. Official State Gazette Number 23, 30 December 1981 [in Spanish].
[10] Act 54/97. The electric sector. Official State Gazette Number 285, 27 November 1997 [in Spanish].
[11] Real Decreto 436/04. de 12 de marzo, por el que se establece la metodología para la actualización y sistematización del régimen jurídico y económico de la actividad de producción de energía eléctrica en régimen especial, 2004 [in Spanish].
[12] APPA. "Libro blanco de las energias renovables en España". Num. 54. Marzo 2005.
[13] Núñez Oliveira E, Martínez Abaigar J. El Clima en La Rioja. Logroño: Consejería de Agricultura; 1991.
[14] Instituto para la Diversificación y el Ahorro de la Energía Boletines varios años 2002–2005. Eficiencia energética y energías renovables. [in Spanish].
[15] Strehler A. Technologies of wood combustion. Ecol Eng 2000;16:25–40.
[16] Appa. Asociación de Productores de Energías Renovables. Madrid. 2003.
[17] Sala Lizarraga JM, y López González LM. Inventario y Plan Energético de la Comunidad Autónoma de La Rioja (CAR). Logroño: Servicio de Publicaciones del Gobierno de La Rioja; 2003.
[18] López González LM, et al. Documentación, artículos y publicaciones diversas. Varios años: Servicio de Publicaciones de la Universidad de La Rioja; 1996–2005 [Acceso restringido].